RETROVIRAL VECTORS FOR DELIVERY OF INTERFERING RNA

FIELD OF THE INVENTION

The present invention relates generally to retroviral vectors for delivering interfering RNA into a cell.

BACKGROUND OF THE INVENTION

RNA interference (RNAi) describes a phenomenon in which the presence of double-stranded RNA (dsRNA) having a sequence that is identical or highly similar to a portion of a target gene results in the degradation of messenger RNA (mRNA) transcribed from that targeted gene (Sharp 2001). Fjose *et al.* have proposed a mechanism for RNA interference [Fjose *et al.* RNA Interference: Mechanisms and Applications. Biotechnology Annual Review, Vol. 7, pp. 10-57 (2001)]. Initially a double stranded RNA sequence (dsRNA) sequence is made available with one strand that is identical or highly similar to a target gene and complementary to an mRNA produced from the transcription of the target gene (the sense strand), and an antisense strand that is complementary to the sense strand. Thus, the antisense sense strand has an identical or highly similar sequence to a portion of the mRNA that results from the transcription of the target gene.

An RNAi nuclease then cleaves the dsRNA into short double stranded fragments whose lengths may vary from 18-25 nucleotides, and binds to the mRNA produced from the transcription of the target gene. An RNAi enzyme having helicase activity then catalyzes an exchange between the short dsRNA and the mRNA so that the antisense strand of the dsRNA anneals to the mRNA replaces the "antisense" strand of the dsRNA, and the mRNA is cleaved at its ends. Consequently, the mRNA is destroyed, and translation of the mRNA molecule does not occur. Moreover, the sense strand of the short dsRNA, which remains bound to the RNAi nuclease, serves as a template for production of a new antisense strand, forming a new dsRNA molecule for use in the destruction of another mRNA produced from the transcription of the target gene. Thus, RNAi demonstrates a catalytic activity. (*Id.*)

The ability to specifically knock-down expression of a target gene by RNAi has obvious benefits. For example, RNAi may be used to generate animals that mimic true genetic "knockout" animals to study gene function. In addition, RNAi may be useful in treating diseases or disorders that arise from the abnormal expression of a particular gene or group of genes, or the expression of a gene having a particular mutation or polymorphism. For example, genes contributing to a cancerous state (e.g., oncogenes) may be inhibited. In

addition, viral genes may be inhibited, as well as mutant genes causing genetic diseases such as myotonic dystrophy, cystic fibrosis, Alzheimer's Disease, Parkinson's Disease, etc. Inhibiting such genes as cyclooxygenase or cytokines may also have applications in treating inflammatory diseases such as arthritis.

Accordingly, what is needed is a vehicle that delivers heterologous RNA into a cell in order to utilize interference RNA to modulate, and particularly, to down-regulate the expression of a particular target gene within a cell.

The citation of any reference herein should not be construed as an admission that such reference is available as "Prior Art" to the instant application.

SUMMARY OF THE INVENTION

Provided herein is a useful and heretofore unknown retroviral viral vectors that permits the delivery of heterologous RNA into a cell in order to utilize RNA interference to modulate the expression of a particular protein.

Broadly, the present invention extends to a retroviral vector for carrying a target gene specific insert into a cell in order to modulate the expression of a target gene. Such a retroviral vector of the present invention comprises a promoter, a polylinker region, and a target gene specific insert comprising double stranded RNA, which comprises a sense portion that is complementary to a portion of the antisense strand of the target gene, and an antisense portion that is complementary to the sense portion. Thus, the sense and antisense portions of the double stranded RNA anneal, and the double stranded RNA folds back upon itself.

Numerous promoters have applications in a retroviral vector of the present invention. A particular example having applications in a retroviral vector of the present invention is the U6 promoter sequence of:

ttcccatgattccttcatatttgcatatacgatacaaggctgttagagagataattagaattaatttgactgtaaacacaaagatattagtaca
aaatacgtgacgtagaaagtaataatttcttgggtagtttgcagtttttaaaattatgttttaaaatggactatcatatgcttaccgtaacttga
aagtatttcgatttcttgcctttatatatcttgtggaaaggacgaaacaccg (SEQ ID NO:7).

Another promoter region having applications in a retroviral vector of the present invention is the H1 promoter, which has a nucleotide sequence of:

-1

ccctttctcaccagagtatgtcttgaatattctaagggtttaggtttctgtaaagtgcaaataccactaaagggtcttgtgtatcgctgtacgt ttataa-100 (SEQ ID NO:14).

Likewise, numerous polylinker regions readily have applications in a retroviral vector of the present invention. Examples of polylinker regions having applications in a retroviral vector of the present invention are

(a) aattc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:1)

(b) aattc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:2);

(c) gatcc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:3);

(d) gatcc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:4)

(e) aattc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:5); and

(f) gatcc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:6).

For a Lentivirus retroviral vector of the present invention, the polylinker sequence can include an AgeI restriction site and an EcoRI restriction site so that a target gene insert such as set forth below can be inserted:

```
AgeI +1                      Loop              Term     EcoRI
CCGGT G (20 more bases) TTCAAGAGA (21 bases) TTTTT GGAA G
    A C (20 more bases) AAGTTCTCT (21 bases) AAAAA CCTT CTTAA
```

This insert contains AgeI and EcoRI restriction sites. The "20 or more bases" can be either the antisense or sense strand of the double stranded nucleotide sequence of the target gene insert. Naturally the "21 bases" also can either the antisense or sense strand. However, it is critical that both of these strands are complementary and anneal so that the double stranded RNA folds back upon itself. Moreover, the 9mer loop described above is only an example. Other loops having other sizes readily can be used in the present invention.

Furthermore, in a retroviral vector of the present invention, the length of the sense and antisense portions of the double stranded RNA in the target gene specific insert can vary. For example, the length of these portions can be 19-30 nucleotides, in particular, 19-25 nucleotides, and more particularly, 19-23 nucleotides, respectively.

Naturally, numerous genes can be the target gene for a retroviral vector of the present invention. Particular examples of a target gene can be a gene associated with a particular

disease or disorder, e.g., an oncogene such as p53 or Mat8. A target gene can also be a gene associated with a neurodegenerative disease or disorder, such as, for example, a mutated amyloid precursor protein or a presenilin gene that is associated with Alzheimer's disease. A target gene can also be a gene that encodes an ion channel protein, a hormone, etc. Indeed, any gene for which it is desirous to interrupt its expression has applications as a target gene for a retroviral vector of the present invention. In a particular example described *infra*, the target gene is p38.

Numerous retroviruses have applications in a retroviral vector of the present invention. For example, a retroviral vector of the present invention may be constructed from a retrovirus such as HIV, MoMuLV ("murine Moloney leukaemia virus"), MSV ("murine Moloney sarcoma virus"), HaSV ("Harvey sarcoma virus"); SNV ("spleen necrosis virus"); RSV ("Rous sarcoma virus"), Friend virus, a murine stem cell virus (MSCV), a lentivirus, or even a defective retroviral vector such as that disclosed in WO95/02697, to name only a few. A particular retrovirus having applications herein is a Murine Stem Cell Virus (MSCV). Another particular retrovirus having applications herein is a modified Lentivirus wherein (a) the endogenous CMV promoter has been removed; and (b) a REV element that binds to a REV response element (RRE) is inserted into the virus.

Moreover, a retroviral vector of the present invention may further comprise a reporter gene, such as hrGFP, Blasti, Hygro, Puro, eGFP-Puro fusion etc.

In another embodiment, the present invention extends to a cell infected with a retroviral vector of the present invention. Such an infection can occur *in vitro*, *in vivo*, or *ex vivo*.

The present invention further extends to a modified Lentivirus vector for carrying double stranded RNA into a cell in order to modify the expression of a target gene, wherein:

(a) the endogenous CMV promoter of the Lentivirus has been removed, said modified Lentivirus vector comprising:

(i) a REV element that binds to a REV response element (RRE) is inserted;

(ii) a U6 promoter sequence of

ttcccatgattccttcatatttgcatatacgatacaaggctgttagagagataattagaattaatttgactgtaaacacaaagatattagtaca
aaatacgtgacgtagaaagtaataatttcttgggtagtttgcagtttttaaaattatgttttaaaatggactatcatatgcttaccgtaacttga
aagtatttcgatttcttgcctttatatatcttgtggaaaggacgaaacaccg (SEQ ID NO:7); and

(iii) a polylinker region;

(iv) a target gene insert that comprises said double stranded RNA,

wherein said double stranded RNA comprises a sense portion that is complementary a portion of the antisense strand of the target gene, and an antisense portion that is complementary to the sense portion so that the sense portion and antisense portion anneal, and the double stranded RNA folds back upon itself.

Numerous polylinker regions have applications in a modified Lentivirus vector of the present invention. Particular examples include, but certainly are not limited to:

(a) aattc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:1)

(b) aattc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:2);

(c) gatcc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:3);

(d) gatcc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:4)

(e) aattc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:5); and

(f) gatcc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:6), to name only a few.

In a modified Lentivirus retroviral vector of the present invention, the polylinker sequence can include an AgeI restriction site and an EcoRI restriction site so that a target gene insert such as set forth below can be inserted:

```
AgeI +1                    Loop              Term     EcoRI
CCGGT G (20 more bases) TTCAAGAGA (21 bases) TTTTT GGAA G
    A C (20 more bases) AAGTTCTCT (21 bases) AAAAA CCTT CTTAA
```

This insert contains AgeI and EcoRI restriction sites. The "20 or more bases" can be either the antisense or sense strand of the double stranded nucleotide sequence of the target gene insert. Naturally the "21 bases" also can either the antisense or sense strand. However, it is critical that both of these strands are complementary and anneal so that the double stranded RNA folds back upon itself. Moreover, the 9mer loop described above is only an example. Other loops having other sizes readily can be used in the present invention.

Furthermore, a modified Lentivirus of the present invention may optionally include a reporter gene, such as Blasti, hrGFP luciferase, etc.

Particular examples of a modified Lentivirus of the present invention described herein are

(a) pLenti-U6-Blasti, which comprises the nucleotide sequence of SEQ ID NO:8 (FIG. 1); and

(b) pLenti-U6-hrGFP, which comprises the nucleotide sequence of SEQ ID NO:9 (FIG. 2).

Furthermore, the present invention extends to a method for modulating expression of a target gene in a cell, comprising infecting the cell with a retroviral vector of the present invention wherein the sense region of the double strand RNA of the gene insert is complementary to the antisense of the target gene, and the antisense region of the double stranded RNA of the target gene insert complementary to the sense region so that the antisense and sense regions of the double stranded RNA anneal and the double stranded RNA folds back upon itself.

The present invention also extends to a Murine Stem Cell Virus (MSCV) vector for carrying double stranded RNA into a cell in order to modify the expression of a target gene, comprising:

(a) a promoter; and

(b) a polylinker region,

(c) a target gene insert comprising the double stranded RNA, which in turn comprises a sense portion that is complementary a portion of the antisense strand of the target gene, and an antisense portion that is complementary to the sense portion so that the sense portion and antisense portion anneal, and the double stranded RNA folds back upon itself.

Various promoter sequences can be used in an MSCV retroviral vector of the present invention. A particular example of such a promoter sequence is the U6 promoter sequence of ttcccatgattccttcatatttgcatatacgatacaaggctgttagagagataattagaattaatttgactgtaaacacaaagatattagtaca aaatacgtgacgtagaaagtaataatttcttgggtagtttgcagtttttaaaattatgttttaaaatggactatcatatgcttaccgtaacttga aagtatttcgatttcttgcctttatatatcttgtggaaaggacgaaacaccg (SEQ ID NO:7).

Another promoter having applications herein is the H1 promoter (SEQ ID NO:14)..

Furthermore, numerous polylinker regions have applications in a MSCV retroviral vector of the present invention. Particular examples include, but certainly are not limited to:

(a) aattc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:1)

(b) aattc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:2);

(c) gatcc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:3);

(d) gatcc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:4)

(e) aattc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:5); and

(f) gatcc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:6), to name only a few.

Optionally, a MSCV retroviral vector of the present invention can also comprise a reporter gene, such as Hygro, Puro, hrGFP, luciferase, or eGFP-Puro fusion.

Particular examples of MSCV retroviral vectors of the present invention include

(a) MSCV-U6-Hygro, which comprises the nucleotide sequence of SEQ ID NO:10 (FIG. 3);

(b) MSCV-U6-Puro, which comprises the nucleotide sequence of SEQ ID NO:11 (FIG. 4); and

(c) MSCV-U6-hrGFP, which comprises the nucleotide sequence of SEQ ID NO:12 (FIG. 5), to name only a few.

Accordingly, it is an aspect of the present invention to provide a retroviral vector having a gene target insert that folds back upon itself to form a duplex, wherein one strand of the duplex is a sense strand and the other strand of the duplex is an antisense strand. When the retroviral vector is processed in the cell, the duplex is cleaved from the vector to form a short dsRNA for use as interfering RNA in modulating the expression of the target gene.

It is another aspect of the present invention to provide a retroviral vector in which the sense strand of the target gene insert is identical or highly similar to a target gene that is associated with a particular disease or disorder. Such a retroviral vector may readily have applications in treating the disease or disorder associated with the expression of the target gene.

It is another aspect of the present invention to provide a cell that has been infected with a retroviral vector of the present invention. Such infection may occur *in vitro*, *in vivo*, or *ex vivo*. As a result of this infection, the expression of the target gene with the cell's genome is

modulated, and in particular, decreased.

It is still another aspect of the present invention to provide a method for modulating the expression of a target gene in cell using interfering RNA, wherein the cell is infected with a retroviral vector of the present invention comprising a target gene insert having a sense strand that is identical or highly similar to the target gene.

These and other aspects of the present invention will be better appreciated by reference to the following drawings and Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1: Nucleotide sequence of modified Lentivirus vector pLenti-U6-Blasti of the present invention containing the Blasti reporter gene and the U6 promoter sequence. A target gene insert for modulating a particular gene can readily be inserted into the polylinker of this vector prior to infection of a cell with the vector.

FIG. 2: Nucleotide sequence of modified Lentivirus vector pLenti-U6-hrGFP of the present invention containing the hrGFP reporter gene and the U6 promoter sequence. A target gene insert for modulating a particular gene can readily be inserted into the polylinker of this vector prior to infection of a cell with the vector.

FIG. 3: Nucleotide sequence of MSCV vector MSCV-U6-Hygro of the present invention containing the Hygro reporter gene and the U6 promoter sequence. A target gene insert for modulating a particular gene can readily be inserted into the polylinker of this vector prior to infection of a cell with the vector.

FIG. 4: Nucleotide sequence of MSCV vector MSCV-U6-Hygro of the present invention containing the Hygro reporter gene and the U6 promoter sequence. A target gene insert for modulating a particular gene can readily be inserted into the polylinker of this vector prior to infection of a cell with the vector.

FIG. 5: Nucleotide sequence of MSCV vector MSCV-U6-hrGFP of the present invention containing the hrGFP reporter gene and the U6 promoter sequence. A target gene insert for modulating a particular gene can readily be inserted into the polylinker of this vector prior to infection of a cell with the vector.

FIG. 6: a schematical view of a modified Lentivirus of the present invention that comprises a GFP reporter gene. (1) is the target gene insert, i.e., the double stranded RNA that folds back upon itself.

FIG. 7: a western blot comparing the expression of p38 in a cell infected with a modified Lentivirus of the present invention that lacks a target gene insert (a control) with the expression of p38 in a cell infected with a modified Lentivirus of the present invention having a target gene insert designed to be complementary to a portion of the cell's endogenous p38 gene. This blot clearly shows that the modified Lentivirus of the present invention decreased the expression of p38 relative to the expression in the control.

DETAILED DESCRIPTION OF THE INVENTION

As explained the above, the present invention broadly extends to a useful and heretofore unknown retroviral vector having applications in delivering interfering RNA into a cell to modulate, and more particularly to down-regulate the expression of a particular target gene. Such a retroviral vector of the present invention comprises:

(a) a promoter,

(b) a polylinker region, and

(c) a target gene specific insert that comprises double stranded RNA, wherein said double stranded RNA comprises a sense portion that is complementary a portion of the antisense strand of the target gene, and an antisense portion that is complementary to the sense portion, so that the sense portion and antisense portion anneal, and the double stranded RNA folds back upon itself.

In a cell, the target gene specific insert that folds back upon itself is processed into a short dsRNA duplex, of which the sense strand can be used as interfering RNA. This interfering RNA modulates, and more particularly, down-regulates the expression the target gene. Surprisingly and unexpectedly, a retroviral vector of the present invention that is used to infect a cell can down-regulate gene expression of the target gene for the life of the cell, as opposed to the mere insertion of naked siRNA into the cell, which has been found to typically down-regulate the expression of the target gene for only 5-6 days.

Since a retroviral vector of the present invention is able to down-regulate the expression of

the target gene, the retroviral vector may have applications in treating a wide variety of diseases or disorders related to the expression of a particular target, or related to the expression of a particular target gene that contains a mutation or polymorphism.

In accordance with the present invention there may be employed conventional molecular biology, microbiology, and recombinant nucleic acid molecule techniques within the skill of the art. Such techniques are explained fully in the literature. See, *e.g.*, Sambrook, Fritsch & Maniatis, *Molecular Cloning: A Laboratory Manual,* Second Edition (1989) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York (herein "Sambrook et al., 1989"); *DNA Cloning: A Practical Approach,* Volumes I and II (D.N. Glover ed. 1985); *Oligonucleotide Synthesis* (M.J. Gait ed. 1984); *Nucleic Acid Hybridization* [B.D. Hames & S.J. Higgins eds. (1985)]; *Transcription And Translation* [B.D. Hames & S.J. Higgins, eds. (1984)]; *Animal Cell Culture* [R.I. Freshney, ed. (1986)]; *Immobilized Cells And Enzymes* [IRL Press, (1986)]; B. Perbal, *A Practical Guide To Molecular Cloning* (1984); F.M. Ausubel et al. (eds.), *Current Protocols in Molecular Biology*, John Wiley & Sons, Inc. (1994).

Therefore, if appearing herein, the following terms shall have the definitions set out below.

A "vector" is an agent, such as plasmid, phage, virus or cosmid, used to transmit genetic material to a cell or organism.

"Heterologous" nucleic acid molecule refers to a nucleic acid molecule not naturally located in the cell, or in a chromosomal site of the cell.

A "nucleic acid molecule" or a "nucleotide sequence" can be used interchangeably, and refer to the phosphate ester polymeric form of ribonucleosides (adenosine, guanosine, uridine or cytidine; "RNA molecules") or deoxyribonucleosides (deoxyadenosine, deoxyguanosine, deoxythymidine, or deoxycytidine; "DNA molecules"), or any phosphoester anologs thereof, such as phosphorothioates and thioesters, in either single stranded form, or a double-stranded helix. Double stranded DNA-DNA, DNA-RNA and RNA-RNA helices are possible.

A nucleic acid molecule is "hybridizable" to another nucleic acid molecule, such as a cDNA, genomic DNA, or RNA, when a single stranded form of the nucleic acid molecule can anneal to the other nucleic acid molecule under the appropriate conditions of temperature and

solution ionic strength (*see* Sambrook et al., *supra*). The conditions of temperature and ionic strength determine the "stringency" of the hybridization. For preliminary screening for homologous nucleic acid molecules, low stringency hybridization conditions, corresponding to a T_m of 55°, can be used, *e.g.*, 5x SSC, 0.1% SDS, 0.25% milk, and no formamide; or 30% formamide, 5x SSC, 0.5% SDS). Moderate stringency hybridization conditions correspond to a higher T_m, *e.g.*, 40% formamide, with 5x or 6x SSC. High stringency hybridization conditions correspond to the highest T_m, *e.g.*, 50% formamide, 5x or 6x SSC. Hybridization requires that the two nucleic acid molecules contain complementary sequences, although depending on the stringency of the hybridization, mismatches between bases are possible. The appropriate stringency for hybridizing nucleic acid molecules depends on the length of the nucleic acid molecules and the degree of complementation, variables well known in the art. The greater the degree of similarity or homology between two nucleotide sequences, the greater the value of T_m for hybrids of nucleic acids having those sequences. The relative stability (corresponding to higher T_m) of nucleic acid hybridizations decreases in the following order: RNA:RNA, DNA:RNA, DNA:DNA. For hybrids of greater than 100 nucleotides in length, equations for calculating T_m have been derived (*see* Sambrook et al., *supra*, 9.50-0.51). For hybridization with shorter nucleic acid molecules, *i.e.*, oligonucleotides, the position of mismatches becomes more important, and the length of the oligonucleotide determines its specificity (*see* Sambrook et al., *supra*, 11.7-11.8). A minimum length for a hybridizable nucleic acid molecule is at least about 15 nucleotides; in particular at least about 40 nucleotides; more particularly the length is at least about 30 nucleotides; more particularly at least about 60 nucleotides, and even more particularly at least 100 nucleotides.

Furthermore, as used herein, the term "standard hybridization conditions" refers to a T_m of 55°C, and utilizes conditions as set forth above. In a preferred embodiment, the T_m is 60°C; in a more preferred embodiment, the T_m is 65°C.

A nucleic acid molecule "coding sequence" or "sense strand" is a nucleic acid molecule or portion thereof for eukaryotic genomic DNA molecules, which encodes a polypeptide or portion thereof with codons of the genetic code in a correct reading frame. It is well known in the art that the following codons can be used interchangeably to code for each specific amino acid:

Phenylalanine (Phe or F) UUU or UUC

Leucine (Leu or L)	UUA or UUG or CUU or CUC or CUA or CUG
Isoleucine (Ile or I)	AUU or AUC or AUA
Methionine (Met or M)	AUG
Valine (Val or V)	GUU or GUC of GUA or GUG
Serine (Ser or S)	UCU or UCC or UCA or UCG or AGU or AGC
Proline (Pro or P)	CCU or CCC or CCA or CCG
Threonine (Thr or T)	ACU or ACC or ACA or ACG
Alanine (Ala or A)	GCU or GCG or GCA or GCG
Tyrosine (Tyr or Y)	UAU or UAC
Histidine (His or H)	CAU or CAC
Glutamine (Gln or Q)	CAA or CAG
Asparagine (Asn or N)	AAU or AAC
Lysine (Lys or K)	AAA or AAG
Aspartic Acid (Asp or D)	GAU or GAC
Glutamic Acid (Glu or E)	GAA or GAG
Cysteine (Cys or C)	UGU or UGC
Arginine (Arg or R)	CGU or CGC or CGA or CGG or AGA or AGG
Glycine (Gly or G)	GGU or GGC or GGA or GGG
Tryptophan (Trp or W)	UGG
Termination codon	UAA (ochre) or UAG (amber) or UGA (opal)

It should be understood that the codons specified above are for RNA sequences. The corresponding codons for DNA have a T substituted for U.

As used herein, the term "portion" with respect to a nucleotide sequence refers to a part of said sequence having a length of at least 19 contiguous nucleotides, but less than the entire nucleotide sequence.

A "promoter sequence" or "promoter" is a nucleic acid molecule regulatory region capable of binding RNA polymerase in a cell and initiating transcription of a downstream (3′ direction) coding sequence. Within the promoter sequence will be found a transcription initiation site (conveniently defined for example, by mapping with nuclease S1), as well as protein binding domains (consensus sequences) responsible for the binding of RNA polymerase. A particular promoter sequence having applications in the present invention includes the U6 promoter sequence, which has the nucleotide sequence of:

ttcccatgattccttcatatttgcatatacgatacaaggctgttagagagataattagaattaatttgactgtaaacacaaagatattagtaca aaatacgtgacgtagaaagtaataatttcttgggtagtttgcagtttttaaaattatgttttaaaatggactatcatatgcttaccgtaacttga aagtatttcgatttcttgcctttatatatcttgtggaaaggacgaaacaccg (SEQ ID NO:7).

Another example of promoter sequence having applications in a vector of the present invention is the H1 promoter (SEQ ID NO:14).

As used herein, the terms "polylinker" or "polylinker region" can be used interchangeably, and refer to a nucleotide sequence that is inserted into a retroviral vector of the present invention and contains a plurality of restriction sites for particular restriction enzymes. Thus, using the particular restriction enzymes a nucleotide sequence can be inserted into a vector of the present invention. Particular Examples of polylinkers having applications in a vector of the present invention include, but certainly are not limited to:

(a) aattc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:1)

(b) aattc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:2);

(c) gatcc gactggcacagcctccagg ttcaagaga cctggaggctgtgccagtc ttttt ggaa a (SEQ ID NO:3);

(d) gatcc gctgggactcctttgcatg ttcaagaga catgcaaaggagtcccagc ttttt ggaa a (SEQ ID NO:4)

(e) aattc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:5); and

(f) gatcc gactccagtggtaatctac ttcaagaga gtagattaccactggagtc ttttt ggaa a (SEQ ID NO:6).

In a particular embodiment of the present invention, e.g. a modified Lentivirus retroviral vector, the polylinker sequence can include an AgeI restriction site and an EcoRI restriction site so that a target gene insert such as set forth below can be inserted:

```
AgeI +1                    Loop              Term     EcoRI
CCGGT G (20 more bases) TTCAAGAGA (21 bases) TTTTT GGAA G
    A C (20 more bases) AAGTTCTCT (21 bases) AAAAA CCTT CTTAA
```

This insert contains AgeI and EcoRI restriction sites. The "20 or more bases" can be either the antisense or sense strand of the double stranded nucleotide sequence of the target gene insert. Naturally the "21 bases" also can either the antisense or sense strand. However, it is critical that both of these strands are complementary and anneal so that the double stranded RNA folds back upon itself. Moreover, the 9mer loop described above is only an example. Other loops having other sizes readily can be used in the present invention.

As used herein, the term "infect" refers to the contamination of a cell with a retroviral vector of the present invention, wherein the cell possesses the gene target within its genome. Thus, infecting the cell with a retroviral vector of the present invention with the proper target gene insert will result in modulating the expression of the target gene in the infected cell.

As used herein, the term "modulate" or "modulating" refers to altering the normal expression of a target gene in an infected cell. In particular, these terms refer to decreasing the amount expression of the target gene in the infected cell as compared to the amount of expression of the target gene measured in the cell prior to infection with a retroviral vector of the present invention, or a decrease in the amount of expression of the target gene in the infected cell as compared to the expression of the target gene in an uninfected control cell.

Retrovirus vectors

As explained above, the present invention extends to a retroviral vector for carrying a target gene specific insert into a cell in order to modify the expression of a target gene, comprising:

(a) a promoter;

(b) a polylinker region;

(c) a target gene specific insert comprising double stranded RNA, wherein said double stranded RNA comprises a sense portion that is complementary a portion of the antisense strand of the target gene, and an antisense portion that is complementary to the sense portion, so that the sense portion and antisense portion anneal, and the double stranded RNA folds back upon itself.

Retroviruses are integrating viruses that infect dividing cells. The retrovirus genome includes two LTRs, an encapsulation sequence and three coding regions (gag, pol and env). Particular examples of retroviruses having applications herein, include, but certainly are not limited to retrovirus such as HIV, MoMuLV ("murine Moloney leukaemia virus" MSV ("murine Moloney sarcoma virus"), HaSV ("Harvey sarcoma virus"); SNV ("spleen necrosis virus"); RSV ("Rous sarcoma virus"), a Friend virus, and a defective retroviral vector such as one disclosed in WO95/02697, which hereby incorporated by reference herein in its entirety.

In general, in order to construct a recombinant retrovirus containing a nucleic acid sequence, a plasmid is constructed which contains the nucleic acid sequence, which in the case of the present invention, is an RNA sequence that comprises a target gene specific insert as

described above, and a polylinker region. Optionally, the RNA sequence can also comprise a nucleic acid that encodes a reporter protein. This construct is then used to transfect a packaging cell line, which cell line is able to supply in trans the retroviral functions, which are deficient in the plasmid. In general, the packaging cell lines are thus able to express the gag, pol and env genes. Such packaging cell lines have been described in the prior art, in particular the cell line PA317 (US4,861,719); the PsiCRIP cell line (WO90/02806) and the GP+envAm-12 cell line (WO89/07150). After the construction, a retroviral vector of the present invention can be purified by standard techniques known to those having ordinary skill in the art. A detailed description of the construction of a retroviral vector of the present invention is set forth *infra*.

A particular type of retrovirus having applications in a retroviral vector of the present invention is a modified Lentivirus, which is able to infect post mitotic cells and/or non-dividing cells. Such types of cells can be found in liver and muscle neurons. In a modified Lentivirus vector of the present invention, the endogenous CMV promoter of a Lentivirus is removed, and a REV element is inserted into the virus.

Anther type of retrovirus having applications in a retroviral vector of the present invention is the MSCV virus.

Administration of a Retroviral Vector of the Invention via Infection, Transfection or Transformation

The present invention further extends to a cell infected with a retroviral vector of the present invention, wherein the infected cell contains the target gene within its genome. Hence, the infection of the cell with a retroviral vector of the present invention can modulate, and particularly, decrease the expression of the target gene within the cell. Such infection can occur *in vivo*, *in vitro*, or *ex vivo*. Numerous types of cells can be infected with a retroviral vector of the present invention. For example, such a cell can be a prokaryotic or eukaryotic cell, e.g., bacterial cells such as *E. coli*, yeast cells or mammalian cells. Furthermore, such cells can be obtained from a biological sample such as, e.g., hair or skin, or body fluids, e.g., blood, saliva or semen, etc. However, as explained above, it is important that the cell contain the target gene within its genome.

Optionally, a cell can also be transformed or transfected with a retroviral vector of the present invention using routine laboratory techniques, e.g., transfection, electroporation, microinjection, transduction, cell fusion, DEAE dextran, calcium phosphate precipitation, lipofection (lysosome fusion), use of a gene gun, or a DNA vector transporter (see, *e.g.*, Wu et al., 1992, J. Biol. Chem. 267:963-967; Wu and Wu, 1988, J. Biol. Chem. 263:14621-14624; Hartmut et al., Canadian Patent Application No. 2,012,311, filed March 15, 1990).

Naturally, transfection or transformation can also occur *in vivo*. For example, a retroviral vector of the present invention can be introduced *in vivo* by lipofection. Liposomes have been used for encapsulation and transfection of nucleic acids *in vitro*. Synthetic cationic lipids designed to limit the difficulties and dangers encountered with liposome mediated transfection can be used to prepare liposomes for *in vivo* transfection of a retroviral vector of the present invention. The use of cationic lipids may promote encapsulation of negatively charged nucleic acids, and also promote fusion with negatively charged cell membranes [Felgner and Ringold, *Science* **337**:387-388 (1989)]. The use of lipofection for the administration of a retroviral vector of the present invention into specific organs *in vivo* has certain practical advantages. Molecular targeting of liposomes to specific cells represents one area of benefit. It is clear that directing transfection to particular cell types would be particularly advantageous in a tissue with cellular heterogeneity, such as pancreas, liver, kidney, and the brain. In particular, such directed transfection is useful with respect to a modified Lentivirus vector of the present invention since Lentivirus is able to infect post mitotic cells and/or non-dividing cells, which can be found in liver and muscle neurons.

Pharmaceutical Compositions Containing A Retroviral Vector Of The Present Invention

The present invention also extends to a pharmaceutical composition comprising a retroviral vector of the present invention and a pharmaceutically acceptable carrier for the administration of a retroviral vector of the present invention. As used herein, the phrase "pharmaceutically acceptable" refers to molecular entities and compositions that are physiologically tolerable and do not typically produce an allergic or similar untoward reaction, such as gastric upset, dizziness and the like. Preferably, as used herein, the term "pharmaceutically acceptable" means approved by a regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly in humans. The term "carrier" refers to a diluent, adjuvant, excipient, or vehicle with which the compound is administered. Such pharmaceutical carriers can be sterile liquids, such as water and oils, including those of petroleum, animal,

vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. Water or aqueous solution saline solutions and aqueous dextrose and glycerol solutions are preferably employed as carriers, particularly for injectable solutions. Suitable pharmaceutical carriers are described in "Remington's Pharmaceutical Sciences" by E.W. Martin.

A pharmaceutical composition of the present invention may be for administration for injection, or for oral, pulmonary, nasal or other forms of administration, and may include diluents of various buffer content (*e.g.*, Tris-HCl, acetate, phosphate), pH and ionic strength; additives such as detergents and solubilizing agents (*e.g.*, Tween 80, Polysorbate 80), anti-oxidants (*e.g.*, ascorbic acid, sodium metabisulfite), preservatives (*e.g.*, Thimersol, benzyl alcohol) and bulking substances (*e.g.*, lactose, mannitol); incorporation of the material into particulate preparations of polymeric compounds such as polylactic acid, polyglycolic acid, etc. or into liposomes. Hylauronic acid may also be used. Such compositions may influence the physical state, stability, and rate of *in vivo* release. *See, e.g.*, Remington's Pharmaceutical Sciences, 18th Ed. (1990, Mack Publishing Co., Easton, PA 18042) pages 1435-1712, which are herein incorporated by reference. The compositions may be prepared in liquid form, or may be in dried powder, such as lyophilized form.

The present invention may be better understood by reference to the following non-limiting Example, which is provided as exemplary of the invention. The following Example is presented in order to more fully illustrate the preferred embodiments of the invention. It should in no way be construed, however, as limiting the broad scope of the invention.

EXAMPLE

Cloning shRNA into Lentiviral Vector called LUG:

Initially, upper and lower strands of short hairpin nucleotide sequences (21 bases of sense strand, 9 bases of loop and 21 bases antisense) are obtained. They can be either produced or purchased from an oligo vender. The two strands are then in one well of a 96-well format.

Then, 50 pmol/ul of the strands are annealed, and 0.05 pmoles of the annealed strands is used to ligate. The oligos were such that the upper and lower strands were combined together in a single well of a 96-well plate. All processes were carried out in a 96- well High-Throughput format.

For the annealing reaction, 5 µl of the oligo mix was added to 45 µl of the annealing mix (40 µl water + 5 µl NEB buffer 2). The mixture was annealed by heating to 98°C for 2 minutes in a thermocycler and then cooled on the bench top for at least 2 hours. The annealed oligos were then diluted to 1:100 and 1 µl of the diluted annealed oligos, i.e., the double stranded DNA of the target gene insert, was ligated into the polylinker of the retroviral vector backbone (which was pre-cut with AgeI and EcoRI). Ligations were carried out overnight at 4°C. 2 µl of the ligation was used to transform 40 µl of SURE cells (Stratagene) and the transformations were plated on 12 well carbenicillin (50 µg/ml) grid plates. The following day, colonies were picked into Super Broth- carbenicillin (50 µg/ml) and sent to HTP sequencing. The cultures were then mini-prepped and sequenced. The sequences were analyzed and positives were maxi-prepped to provide DNA for virus production.

Producing Modified Lentivirus in 293FT Cells:

Transfection Procedure:

One day prior to transfection, trypsinize and count the 293FT cells, plating them at 5 x 10 6 cells per 10 cm plate. Plate cells in 10 ml of growth medium containing serum.

On the day of transfection, remove the culture medium from the 293FT cells and replace with 5 ml of growth medium containing serum (or Opti-MEM ® I Medium containing serum). Antibiotics must not be included.

Prepare DNA-Lipofectamine Ž 2000 complexes for each transfection sample by performing the following:

- Dilute 9 µg of the optimized packaging mix and 3 µg of pLenti expression plasmid DNA (12 µg total) in 1.5 ml of Opti-MEM ® I Medium without serum. Mix gently.
- Mix Lipofectamine 2000 gently before use, then dilute 36 µl in 1.5 ml of Opti-MEM ® I Medium without serum. Mix gently and incubate for 5 minutes at room temperature.
- After the 5-minute incubation, combine the diluted DNA with the diluted Lipofectamine 2000. Mix gently.
- Incubate for 20 minutes at room temperature to allow the DNA-Lipofectamine 2000 complexes to form. The solution may appear cloudy,

but this will not impede the transfection.

4. Add the DNA-Lipofectamine 2000 complexes dropwise to each plate. Mix gently by rocking the plate back and forth. Incubate the cells overnight at 37°C in a CO_2 incubator.

5. The next day, remove the medium containing the DNA-Lipofectamine 2000 complexes and replace with complete culture medium (i.e. D-MEM containing 10% FBS, 2 mM L-glutamine, 0.1 mM MEM Non-Essential Amino Acids, and 1% penicillin/streptomycin).

A skilled artisan should note that expression of the VSV G glycoprotein causes 293FT cells to fuse, resulting in the appearance of multinucleated syncitia. This morphological change is normal and does not affect production of the lentivirus. It should also be noted that in practicing the present invention, one is interacting with infectious materials.

6. Harvest virus-containing supernatants 48-72 hours post-transfection by removing medium to a 15 ml sterile, capped, conical tube. Minimal differences in viral yield are observed whether supernatants are collected 48or 72 hours post-transfection.

7. Centrifuge at 3000 rpm for 15 minutes at +4°C to pellet cell debris.

8. Perform filtration step, if desired

9. Pipette viral supernatants into cryovials in 1 ml aliquots. Store viral stocks at -80°C.

Producing MSCV in GP2-293 Cells:

Cell are maintained in a complete medium of DMEM supplemented with 10%FBS, 100 μg/ml streptomycin, 100 units/ml penicillin G.

Propagating cells from frozen stocks:

1. Thaw vial in a 37° C waterbath.
2. Transfer the cells to a tube containing 9 ml of pre-warmed complete medium.

3. Centrifuge in 1500 rpm for 5 minutes.

4. Remove supernatant.

5. Gently resuspend cells in 10 ml of complete medium and plate in a 10 cm poly-D-lysine coated plate.

6. Incubate cells at 37°C with 5% C02

poly-D-lysine coated plates can be used for the first week to promote adherence after thawing. Subsequently, the cells may be cultured on regular plates.

Maintaining Packaging Cells

1. Aspirate medium , wash cells once with pre-warmed PBS.

2. Add 1ml of trypsin-EDTA to the plate. Incubate for 30 sec –1 min.

3. Add 4 mls of complete medium to inhibit trypsin.

4. Resuspend the cells by pipetting up and down several times.

5. Transfer 1 ml of cells to a 10 cm plate containing 9 ml of complete medium.
The cells should be split 1:5 every 3 days when the cells are at 80% confluence. Moreover, cell should not be over trypsinized since as a result, the cells tend to become clumpy and will not plate down well. Also, never let the cells get over confluent as this affects their packaging ability , and cells after Transfer/Passage # 40 should not be used as their titers are compromised.

Infection of GP2-293 Cells:

Day 1: (around 3pm)

Plate 3 to 3.9 x 106 cells per 10 cm plate (use poly-D-lysine coated plates).

Day 2: (around 12 noon)

4 hours before the infection, re-feed the cells with 10 ml of fresh medium (minus antibiotics).

Infection Method 1 (Calcium Phosphate/HBS)

1. Use 12 μg of expression vector (pMK0.1) (DNA1) and 12 μg VSV-G plasmid (DNA2) per transfection per 10 cm plate.

2. In a tube add :

DNA 1 12 μg

DNA 2 12 μg

A retroviral vector of the present invention can exist as a dsDNA vector so that it can be propagated, such as in a plasmid. However, when it is packaged, it is a retrovirus and infection leads to injection of the virus nucleoprotein core (consisting mostly of gag-derived proteins, RNA vector, and the reverse transcriptase protein). Reverse transcriptase converts the retroviral vector of the present invention back into DNA and allows for stable integration into the genome of a cell infected. Furthermore, the DNA vector integrated (or transiently transfected) serves as the template for RNA polymerase III which binds to U6 promoter and transcribes shRNA from shDNA cloned into the vector. Above DNA1 is DNA vector (to deliver shRNA) and DNA2 is packaging plasmid.

Water

2M $CaCl_2$ 62 μl

Total Vol. 500 μl

3. In a separate tube, dispense 500 μl of 2X HBS.
4. Add the 2X HBS dropwise to the DNA/ $CaCl_2$ mixture whilst vortexing.
5. Incubate at room temperature for 20 minutes.
6. Vortex the DNA/ $CaCl_2$ mixture gently.
7. Add the mixture to the packaging cells dropwise with a pipette.
8. Rock the plate back and forth to evenly distribute the solution.
9. Incubate the cells at 37°C with 5% CO_2.

Transfection Method 2 (Lipofectamine 2000)

1. Use 6 μg of expression vector (pMK0.1) and 6 μg VSV-G plasmid per transfection per 10 cm plate.
2. Add the DNA to a tube.
3. In a separate tube, pipette 72 μl of Lipofectamine 2000 into a 1.5 ml of serum-free medium (Optimem).
4. Mix gently. Incubate at room temperature for 5 minutes.
5. Add the Lipofecatamine/Optimem mixture to the DNA, mix gently.
6. Incubate at room temperature for 15 minutes.

7. Add the DNA/Lipo/Optimem mixture to the packaging cells dropwise with a pipette.

8. Rock the plate back and forth to evenly distribute the solution.

9. Incubate the cells at 37° C with 5% CO_2.

Do not allow the transfection complex to sit on the cells for more than 16 hours.

Day 3: (am)

1. Aspirate the medium.

2. Gently wash the cells once pre-warmed PBS

3. Add 5 mls of complete medium per 10 cm plate in order to concentrate the viral supernatant.

4. Incubate the cells at 37° C with 5% CO_2.

Day 4: (am)

1. Harvest the medium, filter thru a 0.45 micron syringe filter.

2. Aliquot the virus, store at -80° C.

3. Re-feed the cells with 5 mls of complete medium.

This is the "24 hour viral supe" Harvesting the virus from the packaging cell line after 24 hours is 24 hour viral supernatant.

Day 5: (am)

1. Harvest the medium, filter thru a 0.45 micron syringe filter.

2. Aliquot the virus, store at -80°C.

3. Discard the plates.

This is the "48 hour viral supe" Harvesting the virus from the packaging cell line after 48 hours is 48 hour viral supernatant.

For Ecotropic Viruses, package in EcoPack Packaging Cell Line. For AN Amphotropic Virus, package in AmphoPack Packaging Cell line. For a Polytropic Virus, package in GP2-293 Packaging Cells (co-transfect vector with VSV-G expression plasmid)

Results

Using the procedures set forth above to produce a retroviral vector of the present invention, and then infecting cells having the target gene in their genome with a retroviral vector of the present invention, expression of the target gene has been successfully decreased. In a particular, the target gene insert for p38 was used, and the sequence for this target insert is set

forth below.

CCGGTGCAGGAGTTGAACAAGACAATACCTGATTGTCTTGTTCAGCTCCTGCTTT TTGGAAG (SEQ ID NO:13).

FIG. 7 clearly shows that a modified Lentivirus of the present invention having the target gene insert of double stranded RNA of SEQ ID NO:13, which was designed to interfere with expression of p38 in a cell, clearly decreased the expression of p38 in the cell relative to the expression of p38 in a control cell.

The present invention is not to be limited in scope by the specific embodiments describe herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and the accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

It is further to be understood that all base sizes or amino acid sizes, and all molecular weight or molecular mass values, given for nucleic acids or polypeptides are approximate, and are provided for description.

Various publications are cited herein, the disclosures of which are incorporated by reference in their entireties.